Borrowing with Unpaid Bills*

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Abstract

Unpaid utility bills may provide an important source of credit to households. With billing data from a piped water provider in Manila, this paper estimates a consumption and savings model to measure how much households value delaying water bill payments. Estimates suggest that households would require an 8% discount on their water bills in order to commit to always paying on time.

Keywords: credit constraints; consumption smoothing; water utilities.
JEL Codes: O13; E21; L95.

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1. Introduction

Households face a dynamic problem of how to smooth their consumption over time, especially in low-income settings where households have little access to formal credit and risky streams of income (Morduch [1995]). Households often resort to costly money lenders or informal arrangements with family members (Banerjee and Duflo [2007]). Firms may provide an additional channel for consumption smoothing by allowing households to delay their payments for goods and services. In particular, public utilities often tolerate high levels of unpaid bills each month. This source of credit is likely to be economically important to households in developing countries since public utilities cover broad populations and take up at least 5% of household incomes.[1]

When market failures limit formal lending, public utilities may provide efficient, second-best sources of credit. First, poor access to collateral often restricts the availability of lending options to low-income households (Jack et al. [2016]). Public utilities overcome this barrier by threatening disconnection from future service to enforce repayment. Second, poor infrastructure and mobile populations increase the transaction costs of screening and monitoring debtors, which contribute to high interest rates (Jack and Suri [2014]). As part of their business practices, public utilities invest in meter reading and billing systems that may lower these transaction costs. Third, moneylenders and peer-to-peer lending groups often cater to small pools of debtors while public utilities are able to spread default risk across a wide customer base. Despite these advantages, linking credit to consumption creates an inherent inefficiency by incentivizing overconsumption. For example, households may substitute toward piped water and away from other beverages in months where they are credit constrained. Since governments actively regulate public utilities, the extent to which public utilities should also provide credit remains an open policy question (Laffont [2005]).

Technologies that eliminate delayed payments have recently dominated utility policy discussions. Both researchers and policymakers recommend new prepaid metering technologies, which require upfront payment before releasing any services, as effective strategies to prevent nonpayment.[2] Yet, existing analyses have yet to consider how these technologies may impact household welfare by reducing consumption smooth-

[1] Komives et al. [2006] find that households spend 1-2% of their incomes on water and 4% on electricity.

[2] Kojima and Trimble [2016] and Heymans et al. [2014] are broadly supportive of prepaid metering for electricity and water utilities (respectively). Jack and Smith [2016] find that prepaid meters for electricity in South Africa substantially increase utility revenues. Jack and Smith [2015] also argue that prepaid meters may help savings constrained consumers by allowing households to pay small increments each month.

ing.

This paper incorporates delayed payments to public utilities into household consumption and savings decisions in order to evaluate the welfare effects of offering credit through public utilities. I build a dynamic model where each period, households have the option of borrowing with a costly asset as well as with delayed payments to a public utility. Low interest rates on delayed payments induce households to increase their borrowing by overconsuming utility services. The extent to which households value payment flexibility depends on the borrowing costs of other assets, which are often difficult to measure in traditional survey data.

To estimate borrowing costs, I take a structural approach using billing data from a regulated water utility in Manila, Philippines. The estimation leverages months where utility workers visit households and disconnect them if they do not pay their outstanding balances. If borrowing were costless, households would never be disconnected during these visits because they would immediately agree to pay their outstanding balances with cheap loans. Therefore, long and frequent disconnections in response to these visits — especially among households with large outstanding balances — provide evidence of borrowing costs. Using this strategy, I estimate high interest rates for borrowing, consistent with poor observed access to formal credit in Manila with only 3.9% of households having credit cards and 18.7% having bank accounts.[3]

These estimates also allow me to simulate several counterfactual policies. First, when households are required to pay their bills on time (holding all else equal), consumer welfare drops by 52.4 PhP (or 1.2 USD) per household-month, which is equal to 8% of an average water bill. Usage also declines since households no longer have an incentive to overconsume water. Second, I simulate a policy that (1) eliminates delayed payments by charging a high interest rate on unpaid bills, (2) eliminates default risk by preventing households from leaving large outstanding balances when they permanently disconnect, and (3) adjusts prices to ensure that the water utility remains revenue-neutral (consistent with regulation in Manila).[4] This policy reduces social welfare by 72.2 PhP (or 1.6 USD) per household-month. Finally, I use this framework to evaluate implementing prepaid meters in this context. Prepaid meters require steep increases in prices to cover their installation and maintenance costs. As a result, prepaid meters produce even larger reductions in social welfare on the order of 221.0 PhP (or 4.9 USD) per household-month. These results suggest that popular policies to

[3]Statistics are from the Philippines 2014 Consumer Finance Survey.

[4]Laffont [2005] discusses economic reasons for these regulatory structures which are common in both developed and developing country settings.

reduce nonpayment may be welfare reducing by limiting consumption smoothing.

2. Data

Measuring credit through unpaid water bills requires information on monthly water bills at the household level. This paper relies primarily on water-company records collected as part of a research partnership with one of the two regulated, private providers in Manila. This company provided access to monthly billing records for each connection as well as detailed information covering the regulatory structure and costs of production. The monthly billing records include meter readings, total bill due, and payments spanning January, 2010 to May, 2015. Over this timeframe, the total number of connections increase from 900,000 to 1,500,000 as the water company expanded service access. Water connections are split into four categories: residential (90%), semi-business (4%), commercial (5%), and industrial (1%). Since this research focuses on household consumption and savings decisions, only connections coded as residential are included in the analysis.

Since multiple households often share the same connection in Manila, the billing data is merged to survey data that measures the number of households using each connection as well as demographics for the household that owns the connection. Conducted every two years between 2008 and 2012, the survey data cover a total of close to 50,000 water connections.[5] Alongside providing demographic information, this survey data allows for limiting the analysis to connections that each serve a single household in order to map the billing data for each connection into the consumption and savings decisions of a single household.[6] However, previous research from Violette [2019] finds that households using a connection individually tend to have higher demand for water, larger household sizes, and greater likelihood of living in single houses (as opposed to duplexes or apartments) in comparison to households sharing water connections. These differences may limit the generalizability of the findings outside of this subpopulation in Manila. This sample restriction also ensures that household-level data and connection-level data can be referred to interchangeably. Table 9 in Appendix 8.2 includes more details on how the sample is constructed for the analysis.

Because the connection survey data does not include income measures, average

[5]Connection survey documentation indicates that surveyors used stratified random sampling where the number of connections surveyed was proportional to the census population in the smallest administrative census district (Barangay).

[6]Violette [2019] finds that sharing a connection with multiple households affects household water demand through a variety of channels.

monthly income for households in Manila is taken from the 2015 Family Income and Expenditure Survey. The average interest rate for the Philippines is calibrated from the World Bank Databank (2010-2015).

3. Credit through Unpaid Water Bills

Table 1. Mean Characteristics

	Mean	SD	Min	25th	75th	Max
Usage (m3)	24.9	17.0	0.0	14.0	32.0	200.0
Bill	692	927	-4,640	265	854	78,409
Unpaid Balance	1,523	4,611	-4,995	0	1,126	79,904
Share of Months with Payment	0.71	0.45	0.00	0.00	1.00	1.00
Payment Size	924	1,147	0	316	1,082	62,879
Days Delinquent	50.2	133.6	0.0	0.0	31.0	720.0
Delinquency Visits per HH	0.42	0.71	0.00	0.00	1.00	6.00
Share of Months Disconnected	0.04	0.19	0.00	0.00	0.00	1.00

Total Households: 34,406 Obs. per Household: 61.7 Total Obs.: 2,123,335

Bill, Unpaid Balance, and Payment Size are in PhP per household-month.

Unpaid water bills may provide a reliable source of low-cost credit to households because (1) the company tolerates high rates of delinquency before disconnecting them from service and (2) the water company is prohibited from charging any interest on outstanding balances.

At the end of each month, the water company sends meter readers who record monthly consumption for each connection and then use a mobile device to print and deliver the bill to the household in person. The household is then expected to pay the bill by the end of the month. Households have many options to pay their bills with 79% using small payment centers (mall kiosks, gas stations, convenient stores, etc.), 17% paying at local water company offices, and 3% paying over phone, online, or via ATM kiosks.[7] Despite easy payment mechanisms, households rarely pay their bills on time. Table 1 provides summary statistics on the usage, billing, and payment patterns of households. On average, households are 50.2 days behind in their payments. Households also make large, infrequent payments. While the average bill is 691.6 PhP per month, payment sizes average 1,529.0 PhP and households make payments in only 71% of months. These payment patterns leave an average total outstanding balance of 1,523.0 PhP per month.

[7] Figures are tabulated from the connection survey sample.

Given average monthly household incomes of 31,910 PhP and savings rates of 4,836 PhP in Manila, unpaid water bills reach 4.8% of income and 31.5% of savings on average each month. For households at the 20th income percentile, unpaid water bills jump to 10% of monthly income. As a benchmark, Cull et al. [2009] survey microfinance institutions throughout the developing world and find median yearly loan sizes expressed as a share of the 20th percentile of household income at 48% for nongovernmental organizations (NGOs), 160% for nonbank financial institutions, and 224% for banks. These descriptives suggest that a yearly loan from an NGO could be reached with around 5 months of unpaid water bills for households at the 20th income percentile.[8] Moreover, microfinance loans charge high yearly interest ranging from 25% for NGOs to 13% for banks. In comparison, unpaid water bills are interest-free, but households face some risk of service disconnection for delinquency.

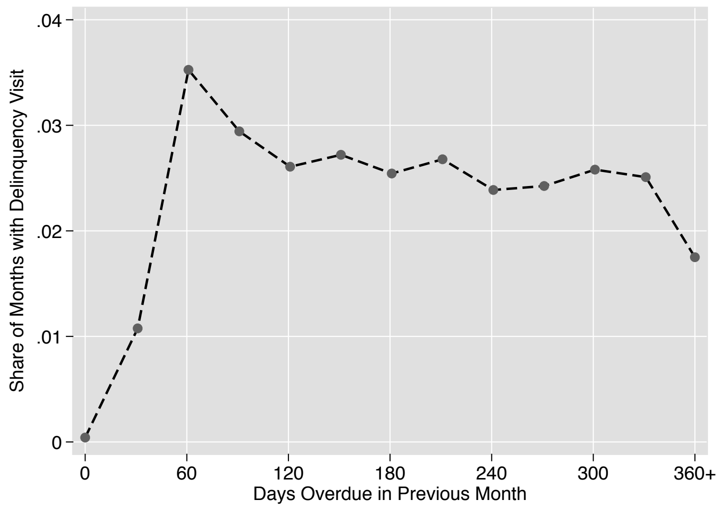
After bills have remained unpaid for at least 60 days, the government regulator permits the water company to visit delinquent households to disconnect their water service.[9] Likely due to time and travel costs, delinquency visits are relatively rare in practice, occurring in only 0.70% of household-month observations. This probability increases to 2.90% for household-months over 60 days overdue. Figure 1 plots the share of months with delinquency visits according to days overdue. The risk of delinquency visits spikes at 61 days overdue before settling to around 2.5% at higher levels of delinquency. Appendix Table 11 predicts delinquency visits with days overdue, outstanding balance, and household characteristics. This exercise finds that days overdue and unpaid balances are strongly and independently correlated with visits while demographic indicators have weaker associations.

When company staff conduct delinquency visits, households often negotiate for additional time to pay their outstanding balances. 96% of households report agreeing to pay within 30 days and the average grace period is 13 days; however, only 25% of connections report having "enough time" to make their payments. For households who fail to pay, disconnection typically involves workers from the water company placing a metal lock on the water meter stopping the flow. In order to reconnect, households must pay a small, one-time fee of 200 PhP on top of settling any outstanding balances. The water company is then required to restore service within 48 hours of receiving full

[8] Deal with income effects on water consumption!

[9] Regulations also require the water company to issue written statements to households, notifying them that their connections will be disconnected in 7 days if their outstanding balances remain unpaid. In practice, only 36% of disconnected households report receiving advanced notice. All percentages are calculated from 924 respondents who report being visited for disconnection in the past year out of 34,406 total respondents in the connection survey.

Figure 1. Share of Households that Receive a Delinquency Visit depending on Days Delinquent in the Previous Month



payment for reconnection, which is confirmed in survey data.[10]

Table 2. Mean Characteristics by Delinquency Visit Status

	Never Visited	Stayers	Leavers
Usage (m3)	24.3	26.2	26.3
Bill	658	761	833
Unpaid Balance	706	2,416	6,520
Share of Months with Payment	0.78	0.60	0.38
Payment Size	829	1,214	1,247
Days Delinquent	18.9	84.9	236.5
Delinquency Visits per HH	0.00	1.32	1.42
Months Disconnected	0.01	0.03	0.31
HH Size	5.2	5.6	5.7
Age of HoH	47.4	44.8	45.8
Low Skilled HoH	0.14	0.17	0.19
Total Households	23,727	8,260	2,419
Total Observations	1,464,945	509,959	148,431

"Never Visited" includes HHs that never receive a delinquency visit.
"Stayers" includes HHs with ≥1 visit and are connected for the last 6 months.
"Leavers" includes HHs with ≥1 visit and are disconnected for ≥1 of the last 6 months.
Bill, Unpaid Balance, and Payment Size are in PhP/month.

Table 2 provides mean characteristics according to whether and how households respond to delinquency visits over the course of the sample. The first column, "Never

[10]Households report being reconnected 2.3 days after payment.

Visited," includes households that never receive a delinquency visit. Since delinquency visits are relatively rare, the majority of observations fall into this category. The second and third columns include households that receive at least one delinquency visit. The second column, "Stayers," also requires that households are connected for the final 6 months of the sample while the third column, "Leavers," includes households that are disconnected for at least one of the final 6 months of the sample.

Leavers are predominantly composed of households that permanently disconnect over the sample period, which likely occurs when households move out of their current residences. These households often leave large outstanding balances that are almost never repaid due to difficulties tracking households across locations. By incentivizing households to pay, frequent delinquency visits provide a strategy for the company to minimize this lost revenue.

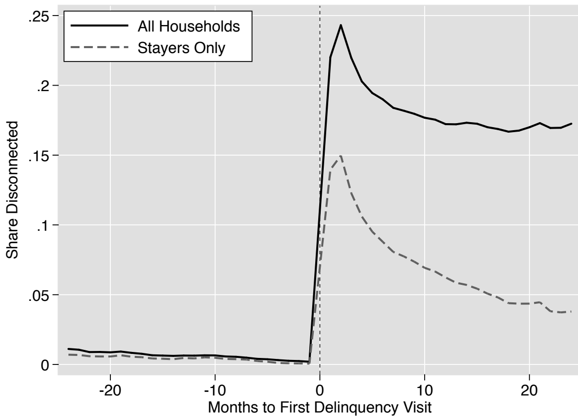
Stayers include households that remain connected at the end of the sample despite receiving at least one delinquency visit over the duration.[11] Compared to households that are never visited, stayers have much higher outstanding balances and days delinquent. Their payments also occur less frequently but have larger average sizes. Stayers spend 3% of the sample period disconnected from service. Until they are able to pay for reconnection, these households likely substitute to alternative water sources including sharing with neighbors, using from deepwells, or purchasing from local water vendors.[12] Stayers also have slightly larger household sizes, younger heads of household, and greater incidence of low-skilled employment than never visited households. These demographic patterns are consistent with lower-income households having greater difficulty paying their bills promptly.

To investigate the timing of household responses to delinquency visits, Figure 2 plots monthly mean outcomes in months relative to the first delinquency visit for each household. Outcomes are plotted separately for all households that experience delinquency visits as well as stayer households who experience visits and also remain connected for the last 6 months of the sample. In the months just preceding a visit, monthly payments (Figure 2d) decrease suddenly, leading to corresponding increases in unpaid balances (Figure 2b) and days overdue (Figure 2c). Average consumption (Figure 2e) increases slightly as well. Prior to disconnection, stayers follow similar patterns but with lower levels of delinquency than the population average.

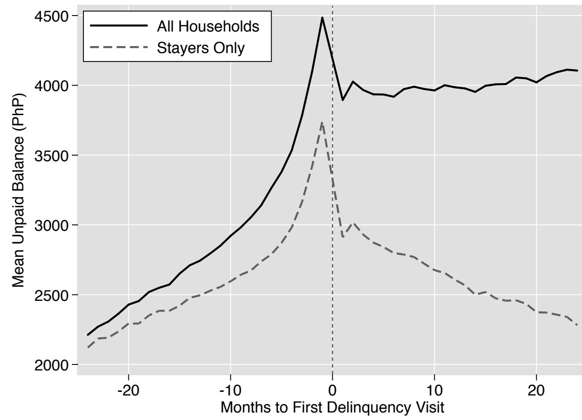
[11] Stayers also excludes 45 households that the company has flagged as "permanently disconnected."

[12] Table 2 indicates that even for households that are never visited, they are disconnected during 1% of months. These disconnections include (1) households that received a delinquency visit before the start of the sample (but later reconnected) and (2) households that notify the water company about their moving plans in advance and therefore, do not need a delinquency visit.

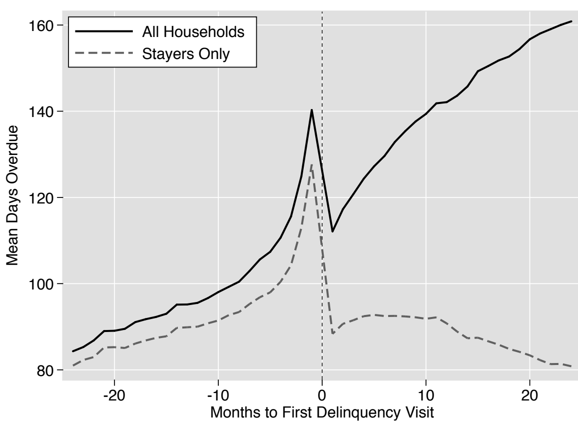
(a) Share Disconnected



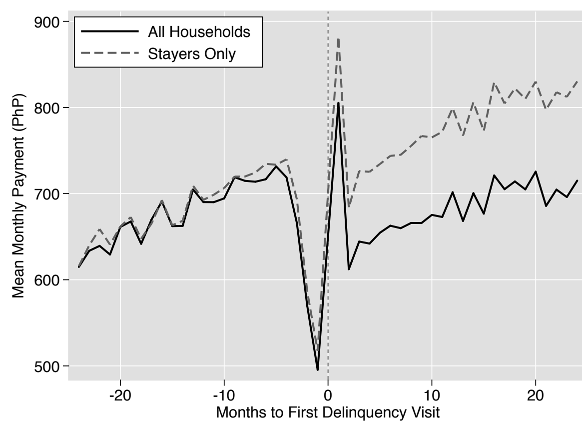
(b) Unpaid Balance



(c) Days Overdue



(d) Monthly Payment



(e) Average Consumption

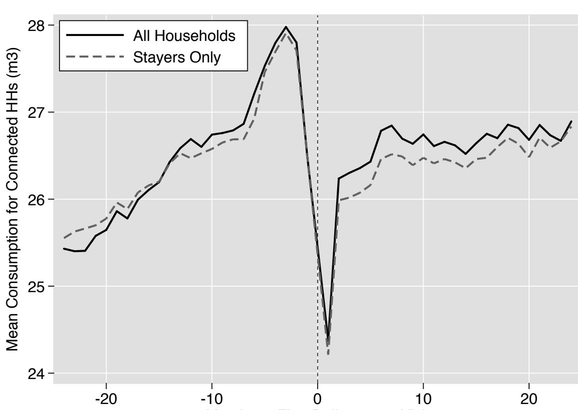


Figure 2. Mean Outcomes around First Delinquency Visit

Figures include all households with delinquency visits. Stayers include only households who are connected for the last 6 months of the sample. Mean monthly payments include zeros when no payment is made.

Immediately following the first delinquency visit, monthly payments spike as many households pay their full outstanding balances to prevent any disconnection. Despite these payments, the average share of households disconnected (Figure 2a) also spikes to around 24% before decreasing, as some households pay for reconnection, and stabilizing at 17%, which is likely composed of households who have permanently disconnected. Stayer households pay more and disconnect less than the population average following a visit. Disconnection rates for stayers spike to 15% before declining to around 4% two years later.[13] The decline among stayers accounts for much of the average decline in disconnection rates across the sample. Although many stayers quickly reconnect within 6 months, reconnections continue accumulating up to one year after a visit.

This descriptive evidence indicates that many households choose to disconnect for long periods before finally paying for reconnection. This behavior is consistent with households facing credit-constraints, which prevent them from taking a low-cost loan to fund immediate reconnection. Instead, households substitute to lower-quality alternative sources of water until they can save enough income for reconnection. Credit constraints would additionally predict that the most delinquent households at the time of the visit may be the most likely to disconnect following a visit. The data support this hypothesis, finding that the share disconnected two months after a visit is 32% for stayers that are over 90 days delinquent at the time of the visit. The corresponding share for stayers under 90 days delinquent shrinks to 4%.

Another hypothesis may be that households choose to stop paying when they leave their homes for vacation or overseas work. This mechanism would likely predict a large decrease in water consumption in the months preceding delinquency visits. Instead, consumption rises consistently between 24 and 2 months before a visit. Consumption then drops one month before, during, and after a visit, before quickly returning to an average level. This dip in consumption likely corresponds to connections that are disconnected for less than a month before being reconnected and having their consumption recorded for that month. Overall, this variation is small given a mean consumption for stayers of 26.2 m3 with a standard deviation of 12.3. Moreover, delinquency visits are relatively rare, which may make their exact timing difficult for households to predict.

[13] Although stayers are connected for the last 6 months of the sample by definition, disconnection rates do not decline to zero since some stayers experience multiple disconnection spells.

4. Model of Household Borrowing and Water Use

To model household borrowing and saving alongside water usage choices, this framework builds on a standard intertemporal utility maximization problem as developed by Deaton [1991]. This approach assumes an infinite time horizon where households choose water usage, borrowing, and savings in each period to maximize current and expected future utility. Household expected utility is given by the following equation

$$E_t\Big[\sum_{\tau=t}^{t-\tau}(1+\delta)^{t-\tau}u(w_\tau, x_\tau)\Big] \tag{1}$$

where utility in each period t is expressed as an increasing and concave function of water consumption, w_τ, and consumption of all other goods, which are collapsed into a single term, x_τ. Households have a rate of time preference $\delta \in (0,1)$. In each period, households face a budget constraint as follows

$$x_t \; + \; p(w_t)w_t \; = \; y_t \; - D_{t+1}f \; + \; S_t \; - \; S_{t+1} \tag{2}$$

where $p(w_t)$ captures the price per unit of water and may change with water use according to the tariff structure. The price of other goods, x_t, is normalized to one. y_t represents household income each period which takes a value of $(1+\theta)\bar{y}$ with probability $\pi \in (0,1)$ and a value of $(1-\theta)\bar{y}$ with probability $(1-\pi)$ where $\theta \in (0,1)$. At the beginning of each period, households can choose whether to temporarily disconnect from water service $D_{t+1} = 1$ or remain connected $D_{t+1} = 0$. If households disconnect or remain disconnected, they pay a fixed cost f. Since temporarily disconnected households are likely to share with neighbors or purchase from local vendors who resell piped water, they are assumed to face the same price schedule as connected households. Temporary disconnection allows households to delay paying their outstanding water balance, especially after receiving a delinquency visit as described in more detail below.

By avoiding payment of water bills, households are able to borrow against their future income. S_t captures total assets chosen in the previous period to be consumed in period t while S_{t+1} captures total assets set aside in period t for consumption in $t+1$

$$S_t = A_t + B_t \tag{3}$$

$$S_{t+1} = \frac{A_{t+1}}{1+r_t^a} + I_t\frac{B_{t+1}}{1+r_t^b} \tag{4}$$

A_t captures standard assets for borrowing and saving. The real interest rate r_a is assumed to take a value of r_l when households are saving ($A_{t+1} \leq 0$) and a value of r_h when households are borrowing ($A_{t+1} > 0$). This wedge in interest rates is intended to capture an institutional context with underdeveloped financial markets where households face high borrowing costs from moneylenders as well as high transaction costs in loaning out their own savings. This assumption is consistent with a recent literature in development economics that emphasizes how households often face institutional savings constraints.[14] Households are unconstrained in their amount of borrowing or saving with this asset.

B_t captures borrowing through unpaid water bills. Households face a real interest rate r_b for borrowing from water bills. To prevent arbitrage cases where households borrow infinitely from water bills to invest in standard assets, r_b is assumed to equal r_h when households are saving through standard assets ($A_t > 0$), and is equal to r_w otherwise. Since the water company is not allowed to charge interest on outstanding balances, r_w is equal to zero in this setting.

I_t determines when households are able to borrow from their unpaid water bills and takes the following form

$$I_t = D_{t+1} + (1 - c_t)(1 - D_t)(1 - D_{t+1}) \tag{5}$$

where c_t indicates whether a household receives a delinquency visit, which occurs with probability $\lambda \in (0, 1)$ in each period and D_{t+1} indicates the household's disconnection choice given their disconnection status D_t. If households receive a delinquency visit ($c_t = 1$) and they choose to remain connected ($D_{t+1} = 0$), then they must pay their full outstanding balance to remain connected, which means that households cannot continue borrowing against their unpaid water bill this period. Similarly, if disconnected households ($D_t = 1$) want to reconnect ($D_{t+1} = 0$), then they also need to pay their outstanding balance. Choosing to disconnect ($D_{t+1} = 1$) allows households to avoid paying their unpaid balances until they choose to reconnect.

Given that households are able to borrow, the amount that they can borrow through unpaid bills is constrained as follows

$$B_t - p(w_t)w_t(1 - D_{t+1})(1 + r_b) \leq B_{t+1} \leq 0 \tag{6}$$

[14] In Kenya, Dupas and Robinson [2013b] and Dupas and Robinson [2013a] estimate large willingness-to-pay for improved savings technologies.

By leaving bills unpaid, households are able to borrow up to their existing outstanding balance, B_t, plus their total bill from water consumption, $p(w_t)w_t$, given that they stay connected to service, $D_{t+1} = 0$. If households choose to disconnect, then they can maintain their existing outstanding balance, but cannot add to this balance through unpaid water use. To capture the fact that water bills are almost never overpaid, households are assumed to be unable to save with this asset.

This framework creates four possible states depending on whether income, y_t, is high or low and whether households receive a delinquency visit given by the indicator variable, c_t. Assuming that the probabilities of reaching each state are uncorrelated with each other yields the following transition matrix between states:

$$T_{t,t+1} = \begin{array}{c} \\ (1+\theta)\bar{y}\text{, no visit} \\ (1-\theta)\bar{y}\text{, no visit} \\ (1+\theta)\bar{y}\text{, visit} \\ (1-\theta)\bar{y}\text{, visit} \end{array} \begin{array}{c} \begin{array}{cccc} (1+\theta)\bar{y}\text{, no visit} & (1-\theta)\bar{y}\text{, no visit} & (1+\theta)\bar{y}\text{, visit} & (1-\theta)\bar{y}\text{, visit} \end{array} \\ \begin{pmatrix} \pi(1-\lambda) & (1-\pi)(1-\lambda) & \pi\lambda & (1-\pi)\lambda \\ \pi(1-\lambda) & (1-\pi)(1-\lambda) & \pi\lambda & (1-\pi)\lambda \\ \pi(1-\lambda) & (1-\pi)(1-\lambda) & \pi\lambda & (1-\pi)\lambda \\ \pi(1-\lambda) & (1-\pi)(1-\lambda) & \pi\lambda & (1-\pi)\lambda \end{pmatrix} \end{array} \tag{7}$$

The problem can be reformulated using a recursive value function approach where the household solves for a function, $V(X_t, z_t)$, that maximizes both current utility and the expected continuation value given current asset-levels and disconnection status captured by X_t as well as current states given by z_t below

$$\begin{aligned} V(X_t, z_t) &= max_{x_t, w_t} \;\; u(x_t, w_t) \; + \; (1+\delta)^{-1} E\Big[\, V(X_{t+1}|z_t) \,\Big| z_{t+1}, T_{t,t+1}\Big] \\ & s.t. \\ & x_t \; + \; p(w_t)w_t \; = \; y_t \; - D_{t+1}f \; + \; S_t \; - \; S_{t+1} \\ & -p(w_t)w_t(1-D_{t+1}) \le \frac{B_{t+1} - B_t}{(1+r_b)} \le 0 \\ & X_t \; = [A_t, B_t, D_t] \\ & z_t \; = [y_t, c_t] \end{aligned} \tag{8}$$

This problem can be divided into two steps: (1) maximizing utility within a given period by choosing w_t and x_t holding asset levels fixed, and (2) choosing asset values to maximize utility over time.

Each period, households face a standard utility maximization problem except in cases where they need to overconsume water to raise enough revenue through unpaid water bills to meet their borrowing goals. For example, households may drink tap water instead of soft drinks or other beverages in months where they are especially credit constrained. Formally, this situation occurs when equation (6) is binding. To solve this problem, let $L = \frac{B_{t+1} - B_t}{1 + r_t^b}$ indicate the amount of revenue needed to be raised through water consumption to fund borrowing levels. Likewise, let $Y = y_t - D_{t+1} f + A_t + B_t - \frac{A_{t+1}}{1+r_t^a} - I_t \frac{B_t}{1+r_t^b}$ equal all other net income. Also, let utility take a Cobb-Douglas shape in water and all other goods with preference parameter, $\alpha \in (0, 1)$. Cobb-Douglas preferences assume that households spend a constant share of their income on water and that the price-elasticity of demand for water is equal to one, which is close to recent estimates in the literature.[15] The Cobb-Douglas utility function is also assumed to take a log-log form, which determines how households smooth income over time.[16]

The price of water is parameterized as a linear function of water use, $p(w) = p_1 + p_2 w$, to approximate the increasing block tariff present in Manila. Suppressing most time subscripts for ease of exposition, the household maximization problem takes the following form within each period

$$
\begin{aligned}
& \quad max_{w_t, x_t} \;\; \alpha \, log(w) \; + \; (1 - \alpha) \, log(x) \\
& s.t. \\
& \quad (p_1 + p_2 w) \, w + x = Y - L \\
& \quad (p_1 + p_2 w) \, w (1 - D_{t+1}) \leq L
\end{aligned}
\tag{9}
$$

Optimal consumption takes a piecewise form depending on whether households have to use more water to satisfy demand for borrowing each period

$$
\begin{aligned}
w^* &= \begin{cases} \frac{p_1 - \sqrt{{p_1}^2 - 8\, L\, \alpha\, p_2 + 8\, Y\, \alpha\, p_2 + 4\, L\, \alpha^2\, p_2 - 4\, Y\, \alpha^2\, p_2}}{2\, p_2\, (\alpha - 2)} & \text{if } L \geq \widehat{L} \\ -\frac{p_1 - \sqrt{{p_1}^2 - 4\, L\, p_2}}{2\, p_2} & \text{if } L < \widehat{L} \end{cases} \\
\widehat{L} &= \frac{Y}{2\, (\alpha - 1)} + \frac{\frac{Y\, p_2}{2} + \frac{{p_1}^2}{8} - \frac{p_1\, \sqrt{{p_1}^2 - \alpha\, {p_1}^2 + 8\, Y\, \alpha\, p_2}}{8\, \sqrt{1 - \alpha}}}{p_2}
\end{aligned}
\tag{10}
$$

where $\widehat{L}$ captures the point at which revenue demanded for borrowing is exactly generated by the household's optimal consumption. When borrowing demand outpaces revenue from optimal consumption (ie. $L < \widehat{L}$), then households must deviate from their optimal consumption choice and instead consume enough water to exactly satisfy borrowing demand. This overconsumption captures a possibly important inef-

[15] Violette [2019] finds an average price elasticity of 0.84 in this setting while Szabó [2015] finds an average price elasticity of 0.98 in South Africa.

[16] CITE SOME LITERATURE HERE?!

ficiency associated with using unpaid water bills as a source of credit. Combining optimal consumption in equation (10) with the budget constraint in equation (2) and the utility function in equation (9) provides an indirect utility function as a function of prices, income, and assets. The full indirect utility function is given by equation (11) in Appendix 8.3.

Given indirect utility in each period and a discount rate that is greater than the return on savings so that households do not save infinitely, $\delta > r_l$, households solve for a stationary value function in (8) that maximizes utility by mapping any combination of asset levels into period t into future asset levels in period $t+1$.

5. Estimation and Results

The goal of the estimation strategy is to map variation in payment behavior, disconnection rates, and average monthly usage levels into estimates of income variation, preferences for water, and the degree of credit constraints faced by households.

Table 3 describes parameters that assumed or calibrated prior to estimation. The monthly savings interest rate is calibrated to the prevailing interest rate in the Philippines over this time period. The estimation uses a monthly discount rate of 2%, which implies an annual discount rate of 26.8% and falls in the range of recent structural and experimental estimates.[17] Since the discount rate of 2% exceeds the calibrated savings interest rate of 0.3%, households are able to solve for a well-defined value function.

To measure prices, the highly non-linear tariff structure is approximated by a linear function of monthly usage as described in more detail in Appendix 8.4. This simplification allows for computational tractability within this dynamic model.[18] This approach also parallels average pricing models of consumer demand for utilities as suggested by Ito [2014].

Without detailed household income data in the water connection survey, the estimation includes average income in Manila as measured by the Family Income and Expenditure Survey. This method may overestimate true average household income because the estimation excludes shared water connections, which tend to used by poorer households. At the same time, this approximation may underestimate true household

[17] Andreoni and Sprenger [2012] estimate rates between 25% and 35% in an experimental setting and confirm exponential discounting. Laibson et al. [2007] use a similar consumption-savings structural approach and recover a discount rate of around 15%. Gourinchas and Parker [2002] use a similar structural approach finding a lower discount rate of around 5%.

[18] Violette [2019] and Szabó [2015] carefully capture non-linear pricing incentives with static models that are very computationally expensive.

income to the extent that the Family Income and Expenditure Survey records households that are unconnected to piped water and tend to be significantly poorer.[19] While the size of monthly income shocks are estimated, households are assumed to face equal probabilities of high and low income shocks in any particular month.

Table 3. Calibrated and Assumed Parameters

Savings Interest Rate	r_l	3.6%	Philippines data from World Bank Databank (2010-2015)
Water Interest Rate	r_w	0%	Regulators prevent charging interest
Discount Rate	δ	2%	Mean of structural estimates from literature†
Tariff	$(p_1 + p_2 w)$	$(20.2 + 0.2w)$	Estimated price by water usage (See Appendix 8.4 for details)
Mean Inc. (PhP)	$\bar{y}$	31,910	Family Income Expenditure Survey (2015) for Manila
High Inc. Risk	π	50%	Assumed to ensure symmetric income shocks
Visit Risk	λ	4.04%	% of months with a visit among stayers with >31 days overdue

All measures are monthly. Annual rates are converted to monthly rates as follows: Monthly Rate = $(1 + \text{Annual Rate})^{1/12} - 1$

† See Andreoni and Sprenger [2012], Laibson et al. [2007], and Gourinchas and Parker [2002] for structural δ estimates.

The last term needed for estimation is the risk of receiving a delinquency visit each month. Since key parameters are identified by the share of households that disconnect in response to delinquency visits, the estimation sample is limited to stayers and risk of delinquency visits is calculated for this sample. Table 12 in Appendix 8.5 includes detailed descriptive statistics for stayer households and Figure 4 provides the probability of receiving a delinquency visit conditional on the days delinquent in the previous month. Focusing on stayers may limit the generalizability of the results, especially given that stayers differ demographically from the population of households as shown in Table 2.

Given assumed and calibrated parameters from Table 3, the estimation strategy is able to recover parameters described in Table 4 using moments in the data. Due to computational limitations, the estimation assumes a representative household and therefore, recovers a single set of parameters that apply to behavior for all households. Average consumption primarily identifies household water preferences. By assuming Cobb-Douglas preferences, identification rests on the assumption that household price elasticity is equal to one so that the preference parameter, α, can be interpreted as the constant share of the budget that households use on water.

Since surveys do not measure monthly household income variation in Manila, the estimation strategy is designed to recover the size of monthly income variation that rationalizes the amount of unpaid water bills observed in the data. Under the structure

[19] The 2010 Census of Population and Housing finds around 5 to 6% of households were unconnected to piped water (Violette [2019]).

of the model, greater income variation increases household demand for credit, which in turn increases the amount of unpaid water bills. This approach assumes that households choose not to pay their water bills in order to smooth their consumption over time. This assumption may not be valid in cases where households pay their bills infrequently because they face fixed travel or other hassle costs in making each payment. As discussed in Section 3, households have a variety of payment options available to them including through local convenience stores, online, and over the phone, which suggests that the fixed costs of making each payment may be small.

The fixed cost of disconnecting and using from an alternative water source is recovered from the share of households that disconnect in response to a delinquency visit. Disconnecting allows households to avoid immediately paying their outstanding water balances. Therefore, high disconnection rates suggest low fixed costs of being disconnected.

The borrowing rate from standard assets is identified from differential disconnections rates in response to delinquency visits for households over and under 90 days overdue at the time of a visit. This identification strategy leverages the intuition that households with large debts at the time of a visit would require large loans from standard assets in order to remain connected. Therefore, high borrowing rates may disproportionately drive these households to disconnect in response to a visit. This identification strategy requires the assumption that households over and under 90 days overdue at the time of a visit face equal fixed costs of remaining disconnected. For example, if more delinquent households have better outside options for water, then this approach would wrongfully attribute their high disconnection rates to high borrowing rates. Also for this approach to be valid, households must be unable to predict the exact timing of delinquency visits. While Appendix 11 provides some evidence that the timing of delinquency visits is correlated with demographics and payment behavior, delinquency visits are relatively rare events, and only 36% of disconnected households reported receiving advanced warning from the water company.

Table 4. Parameters to be Estimated

Parameters		Main Identifying Moments
Water Preference	α	Mean Usage
Income Shock Magnitude	θ	Mean Outstanding Balance
Fixed Cost of being Disconnected	f	% Disconnected 1-4 months post visit
Borrowing Rate from Standard Assets	r_h	% Disconnected 1-4 months post visit given 90+ days overdue when visited

The estimation routine solves the household's problem in equation (8) through value function iteration over across a grid of asset values. Households can choose over 25 values of the standard asset, A_{t+1}, evenly spaced across a normal distribution with a standard deviation of 10,000, a minimum of -17,688, and a maximum of 17,688. Households can also choose how much to borrow from unpaid water bills, B_{t+1}, over 26 values evenly spaced across a normal distribution truncated above at 0 with a standard deviation of 3,800 and a minimum of -7,835. The additional choice of whether to stay connected each period, D_{t+1}, brings the total possible number of asset combinations to 1,300.

The estimation strategy uses a simulated method of moments approach, which chooses parameters to minimize the sum of squared distances between simulated and true moments, weighted by their average values in the data. To generate simulated moments, the estimator creates a random 5,000 month chain of states according to the transition matrix (equation (7)) and calculates the household's predicted asset and consumption choices across these states (assuming asset levels of zero to start).[20]

Table 5 provides the estimation results. The Cobb-Douglas preference for water consumption is estimated to be 0.025, which is consistent with households' average budget share dedicated to water in Manila. The estimated income shock of 0.207 implies that household incomes either increase or decrease by 20.7% of average income with 50% probability each month. This estimate can also be interpreted as measuring the coefficient of variation (CV) of income and falls on the lower end of previous estimates in the literature.[21] Hannagan and Morduch [2015] use monthly financial diaries in the US to calculate CVs of 0.39 for average households and 0.55 for households below the poverty line. Using household surveys from Mexico, Amuedo-Dorantes and

[20]See Laibson et al. [2007] and Gourinchas and Parker [2002] for similar approaches to estimation.

[21]The coefficient of variation (CV) measures the standard deviation of monthly household income divided by average household income (Hannagan and Morduch [2015]).

Pozo [2011] calculate CVs between 0.29 and 0.46, which more closely resemble the estimate in Table 5.

The estimation recovers a fixed cost of being disconnected of 198.9 PhP/month. Previous research uses a static, structural approach to estimate a long-term monthly fixed cost from using alternative water sources of 130 PhP/month (Violette [2019]). While these estimates fall in a similar range, this paper produces a larger estimate of the fixed-cost likely because being suddenly disconnected from piped water leaves little time for households to search for or invest in low-cost alternative sources for water.

The borrowing rate from standard assets is estimated to be 3.8% per month, which implies an annual interest rate of 56.2%. This estimate is substantially lower than the 20% per month interest rate that Karlan and Zinman [2009] document as being commonly charged by moneylenders in Manila. Despite this high interest rate, Karlan and Zinman [2009] document that at least 30% of their sample of microentrepreneurs report taking credit from moneylenders at these rates. The estimated borrowing rate of 3.8% is more similar to microloans of 1,000 PhP at 2.5% monthly interest offered to rural Filipino households as part of a microfinance experiment conducted by Giné and Karlan [2014].[22]

Table 5. Estimates

Parameters		Estimates
Water Preference	α	0.025
		(0.00013)
Income Shock Magnitude	θ	0.207
		(0.0060)
Fixed Cost of being Disconnected (PhP)	f	198.9
		(4.1719)
Borrowing Rate from Standard Assets	r_h	0.038
		()
Households		8,260
Household-Months		509,959

Standard errors in parentheses are bootstrapped at the household-level.

Table 6 provides both moments in the data used for estimation as well as other

[22] The annual interest rate of 56.2% is well exceeds than the average 13 to 25% range offered by microfinance providers worldwide surveyed by Cull et al. [2009]. Two possible reasons for this discrepancy are that (1) institutional reasons unique to Manila may limit lenders' abilities to offer low rates and (2) subsidies may allow many microfinance providers to offer below-market interest rates.

moments to help evaluate model fit. While the model is able to almost exactly match average usage and outstanding balance, the model has more difficulty matching the slow decline in disconnection rates observed after delinquency visits. The model instead predicts that households who disconnect in response to a delinquency visit will quickly reconnect over the following four months. One explanation for this discrepancy may be that the distribution of income shocks does not allow for serial correlation so that households quickly recover from negative shocks. In reality, households may be disconnecting in response to longer-term negative income shocks like job loss or illness. A similar pattern exists for disconnection conditional being over 90 days overdue when visited.

Table 6. Model Fit

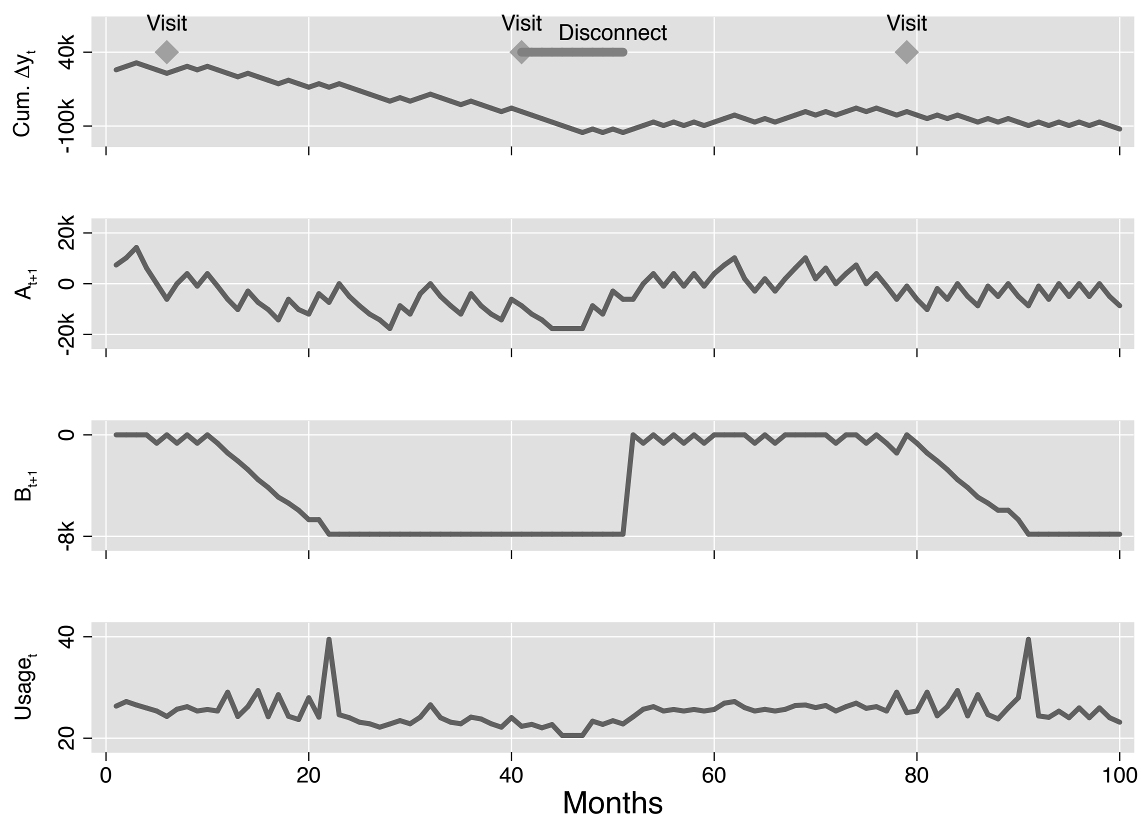
Moments	Data	Predicted
Used in Estimation		
Mean Usage (m3)	26.20	26.20
Mean Outstanding Balance (PhP)	2415.8	2341.1
% Disconnected Post-Visit		
1 month	0.13	0.12
2 months	0.14	0.10
3 months	0.12	0.06
4 months	0.10	0.05
% Disconnected Post-Visit given 90+ days overdue when visited		
1 month	0.30	0.28
2 months	0.32	0.23
3 months	0.26	0.13
4 months	0.23	0.11
Unused in Estimation		
SD Usage	12.3	2.4
SD Outstanding Balance	3588.7	2634.7
Corr. Usage and Out. Bal.	0.31	-0.02

"SD" stands for standard deviation and "Corr." stands for correlation. "Out. Bal." stands for outstanding balance. Standard deviations in the data are calculated with variation within households.

The model has difficultly matching moments that were not used in the estimation. Since log-utility encourages households to smooth their consumption over time, this model predicts very little variation in usage levels. By contrast, high observed variation in usage is likely driven by the fact that households are likely to face idiosyncratic shocks to their water demand each month as household members travel for work, other families come to visit, or Manila experiences a heat wave. A more complete model may include a term for indiosyncratic water shocks although it is unclear whether these shocks would substantively affect the model's predictions over income smoothing across time. While having difficulty matching usage variation, the model is able to generate over half of the observed variation in outstanding balances.

In terms of the correlation between usage and outstanding balances, the data find a positive relationship, which suggests that households may take on water debt to fund extra consumption in months where they face large, positive shocks to their water demand. In the model, positive income shocks reduce demand for water debt and increase demand for water. Negative income shocks reduce demand for water while increasing demand for water debt. Therefore, in some cases, households use more water during negative income shocks in order to increase their borrowing limits. On net, the model finds zero average correlation between outstanding balances and usage.

Figure 3. 100 Months of Simulated Data around a Period of Disconnection



Note: 100 months are chosen to center around the first disconnection event in the 5,000 month random sequence of states used in estimation. "Visit" indicates months with a delinquency visit with a diamond. "Disconnect" indicates months disconnected with a thick line. Cum. Δy_t measures cumulative shocks to income in PHP, A_{t+1} indicates the optimal standard asset position in PhP, B_{t+1} indicates the optimal water borrowing in PhP, and Usage_t indicates water consumption in m3.

To build intuition, Figure 3 provides 100 time periods of simulated data from the model. These 100 time periods are chosen to center around the first disconnection occurrence in the 5,000 month random sequence of states used in the estimation. The first panel in Figure 3 indicates the cumulative, exogenous income shocks faced by the household. This sample features an extreme period of income loss with negative shocks greatly outweighing positive shocks to income. Positive shocks only begin to outweigh negative shocks at around 50 months. Indicators for when households receive delinquency visits as well as whether they choose to remain disconnected are also nested in this first panel. Over the course of 100 months, the household experiences three visits, the second of which leads the household to disconnect for around 12 months. This disconnection corresponds to the period where the household has accumulated the least income.

The second panel indicates the household's choice of asset position, A_{t+1}, in each month. Asset position closely tracks income realizations as households increasingly borrow (moving into very negative positions) following a long series of negative income shocks. At around the time of disconnection, the household chooses to borrow the maximum allowed by the grid of assets chosen for the simulation. Positive income shocks then allow the household to borrow less and begin saving at around 60 months.

The third panel indicates the household's borrowing through unpaid water bills, B_{t+1}. The household increases its borrowing more slowly than with standard assets since each month's total borrowing is limited by the household's current water bill. Matching the downturn in income, households continue borrowing before quickly reaching the maximum borrowing allowed by the grid of assets chosen for the simulation. With few positive income shocks, households remain at this maximum borrowing level for at least 24 months. When the second delinquency visit occurs around 40 months, households are still borrowing the maximum from unpaid water bills and therefore, instead of choosing to pay their outstanding balance, these households choose to disconnect until they the receive enough positive income shocks to pay their full water bill and reconnect to service around month 55. During the third and last delinquency visit, the household's outstanding balance happens to be relatively small so the household pays the balance to remain connected.

The fourth panel indicates households water usage patterns over the same 100 months. Usage begins to spike as the household increases it usage to fund borrowing through unpaid water bills. The largest spikes in usage occur when the household moves to the maximum level of borrowing allowed by the grid of assets chosen for the simulation. Because of the step-size chosen for the asset grid, moving to the largest borrowing level requires a jump in unpaid bills of around 1,000 PhP. Since the average bill is around 600 PhP, the household needs to almost double its usage to fund this jump in unpaid borrowing. These spikes in usage measure the extent to which borrowing from unpaid water bills may distort water usage choices, adding an additional friction associated with borrowing from water bills. After maximizing water borrowing at around 24 months, usage begins to stabilize at lower levels, mirroring the long string of negative income shocks faced by the household.

6. Counterfactual Policies

To measure how much households value credit from unpaid water bills, the model is able to examine household welfare in a counterfactual setting where households are unable to borrow from their water bills. Table 7 includes outcomes for the current setting in Manila in Column (1) and for a counterfactual setting without water borrowing in Column (2), which is captured by raising the interest rate for water borrowing to 100% and holding all else equal. The first row calculates compensating variation equal to 52.4 PhP/month associated with losing access to water credit. This estimate suggests that households would require at least 52.4 PhP/month (or about 1 USD) greater income to eliminate access to water credit. Given an average water bill of 691.6 PhP/month, this estimate would translate into households paying around 8% smaller bills each month.

Eliminating credit access also decreases mean usage by 4.8% as shown by columns (1) and (2) in the second row of Table 7. Reducing credit access lowers the extent to which households can smooth their consumption over time while also removing the incentive for households to overconsume water in order to finance water borrowing. Given that households spend around 2.2% of their income on water, this estimate is roughly proportional to similar evidence from South Africa where restricting credit access with prepaid electricity meters produced a 13% reduction in usage and where households spend around 8-10% of their income on electricity (Jack and Smith [2016]).[23]

[23] Jack and Smith [2016] also propose other mechanisms that may account for reductions in usage such as transaction costs and intra-household bargaining constraints.

Table 7. Counterfactual Policies

	(1) Current	(2) No Water Borrowing	(3) No Water Borrowing and Revenue Neutral	(4) Prepaid Metering and Revenue Neutral
Compensating Variation (PhP)	–	-52.4	-72.2	-221.0
Mean Usage (m3)	26.20	24.93	24.91	21.54
Water Borrowing Interest Rate	0%	100%	100%	–
Price Intercept p_1 (PhP/m3)	20.23	20.23	20.24	26.63
Disconnection Rebate (PhP)	19.1	19.1	0	0
Delinquency Visit Cost (PhP)	6.3	6.3	0	0
Opp. Cost of Lending (PhP)	7.4	7.4	0	0
Marginal Cost (PhP/m3)	5	5	5	5
Additional Metering Cost (PhP)	0	0	0	51

All values are at the household-month level.

This structural model also provides a useful opportunity to evaluate the total welfare effects of implementing policies to reduce delinquency. I consider a policy that (1)eliminates borrowing by raising the water interest rate to 100% and (2) adjusts water prices to ensure that the company remains revenue-neutral. The regulatory structure in Manila as well as many other developing cities ensures that prices for water are regulated to exactly cover all production costs (Hoque and Wichelns [2013]).

Eliminating borrowing affects the costs of the water company in four main ways

1. *Opportunity Cost of Lending*: Currently, the water company faces an opportunity cost for the loans extended to households in the form of unpaid bills. Assuming that the water company would have been able to invest this money at an average annual interest rate of 3.6%, the opportunity cost of lending averages 7.4 PhP per household-month, which would be recouped by the water company in a counterfactual without delayed payments.[24]

2. *Delinquency Visit Cost*: Without water borrowing, the water company would no longer need to conduct delinquency visits. Conversations with the water company suggest that travel costs make up the majority of the costs for any service performed on a water meter. Since the company requires a 200 PhP fee to reconnect disconnected households, I assume that delinquency visits cost the same

[24]Interest rate reflects the average between 2010 and 2015 as reported by the World Bank Databank.

amount to the water company. Conditional on being delinquent, households receive visits in 4.04% of household-month observations, which implies an average delinquency visit cost to the company of 6.3 PhP per household-month.

3. *Marginal Costs*: The water company reports a marginal cost per cubic meter of consumption equal to 5 PhP.

4. *Disconnection Rebate:* Currently, the water company is exposed to default risk where households that permanently disconnect from the water company often leave large outstanding balances that are never paid. On average, 0.0015 households permanently disconnect per household-month. These households that permanently disconnect leave average outstanding balances of 12,859 PhP. These estimates imply household savings equal to an average of 19.1 PhP per household-month. In practice, households enjoy all of these savings in the final few months that they remain connected. However, since households use water indefinitely in the model, the counterfactual exercise captures these savings by assuming that households receive a monthly fixed disconnection rebate of 19.1 PhP. This approach implies the following assumptions

    - By allowing households to spread these savings over time, this assumption is likely to overstate the true benefits to households from leaving unpaid bills.
    - By assuming that households receive fixed rebates, this approach ignores any incentives that households may face to overconsume in their final months connected (since households may behave as if they face an effective price of zero in these months). Appendix 8.6 finds some evidence of overconsumption before permanent disconnection.
    - These exercises assume that household decisions over when and whether to permanently disconnect from service are unaffected by changes in billing flexibility.
    - This approach assumes that under a counterfactual setting with a high borrowing interest rate, households always pay their bills on time even when they are about to permanently disconnect. This assumption may be reasonable since with a high borrowing interest rate, the average household will have an incentive to pay their bills on time except when they are close to permanently disconnecting. Since permanent disconnections are rare, the water company can reasonably maintain the expectation that households will be

disconnected as soon as they stop paying their bills. This threat would likely ensure that households always pay their bills on time.

The following expression calculates the fixed revenue raised by the water company per household-month given prices, p_1 and p_2, and a marginal cost, MC, per m3 of usage

$$REV(p_1, r_b, Y) = \Big(p_1 - MC + p_2\, w^*(p_1, p_2, r_b, Y) \Big)\; w^*(p_1, p_2, r_b, Y)$$

I then solve for the price intercept, p_1', such that the current revenue with zero borrowing rate is equal to revenue under a counterfactual where the borrowing rate is equal to 100% and the water company experiences cost savings. Adjusting the price intercept, p_1, preserves the slope of the tariff structure, which likely reflects equity concerns among policy makers in Manila. p_1' solves the following expression

$$\begin{aligned}\sum_t REV_t(p_1, r_b = 0, Y_t) = \sum_t & REV_t(p_1', r_b = 1, Y_t - \text{Disc. Rebate}) \\ & - (\text{Opp. Cost of Lending} + \text{Visit Cost} + \text{Disc. Rebate})\end{aligned}$$

In the counterfactual, cost savings reduce the amount of revenue needed to be raised to stay revenue neutral. At the same time, eliminating borrowing in the counterfactual lowers water consumption, which reduces revenue since prices are well above marginal costs. Table 7 finds that these two effects almost exactly offset each other, producing almost identical prices in the current setting in Column (1) and the counterfactual without water borrowing in Column (3). Removing water borrowing while keeping similar prices results in a drop in average usage between Columns (1) and (3) that is nearly identical to the drop in usage between Columns (1) and (2).

According to the first row of Table 7, households would require a compensating monthly payment of at least 72.2 PhP in order to move from the current setting in Column (1) to a revenue-neutral counterfactual without borrowing in Column (3). Although prices remain almost identical in Column (3), revenue neutrality ensures that households no longer receive a monthly disconnection rebate of 19.1 PhP, which almost exactly accounts for the difference in compensating variation between columns (2) and (3).

I then simulate the effects of introducing prepaid metering technologies and adjusting water prices to similarly account for their costs. By requiring households to pay upfront for their water usage, these meters provide an alternative strategy for eliminating any access to credit through unpaid water bills. These technologies have become increasingly popular for both electricity and water utilities throughout the developing world.[25] These technologies may be especially useful in contexts where other factors drive delinquency instead of solely the demand for consumption smoothing. For example, Szabó and Ujhelyi [2015] suggest that low levels of trust in local government and perceptions of fairness may drive some nonpayment behavior. While these factors are not explicitly modeled in this context, this exercise may still provide a useful lower bound for evaluating the effects of prepaid metering programs.

Prepaid meters introduce an additional cost for the water company in terms of purchasing and installing this new technology. Heymans et al. [2014] surveyed eight large water providers that implemented prepaid meters in developing countries and found that each prepaid meter costs about four times as much as a standard meter and requires replacement every 7 years. In the context of Manila, each standard meter costs around 1,500 PhP and is replaced around every 6 years and 3 months, bringing the monthly cost to 20 PhP/month.[26] Assuming that a prepaid meter costs 4 times as much as a standard meter with a replacement rate of 7 years, the estimated monthly cost of a prepaid meter would be 71 PhP/month. Therefore, prepaid meters imply an additional cost of 51 PhP/month per household.[27]

Column (4) of Table 7 includes the results of the prepaid metering counterfactual. To cover the much higher costs of prepaid meters, the price intercept, p_1, increases by around 31.6% as indicated by the third row. Households also no longer receive a disconnection rebate of 19.1 PhP per month. With higher prices and without water credit, households lower their consumption by 17.8% under prepaid metering compared to the current setting in Column (1). In order to be indifferent between the current setting and a world with prepaid metering, households would need to receive 221.0 PhP/month in compensation. Taken together, these results provide suggestive evidence that prepaid metering would be welfare reducing in this context.

7. Conclusion

Limitations go in the CONCLUSION!!!!

[25]See Jack and Smith [2016] and Northeast Group [2014] for electricity utilities and Heymans et al. [2014] for water utilities.

[26]The water company provided additional documentation of costs and frequency of meter replacement for residential households.

[27]Heymans et al. [2014] also report that the fixed administrative costs of installing and monitoring new meters account for less than 4% of the total costs of switching to prepaid meters while the bulk of the expenses come from purchasing new meters. By focusing on meter replacement, this exercise is likely to capture the majority of switching costs associated with prepaid metering.

By focusing on consumption smoothing, this paper abstracts away from several other consequences of utility billing policy. First, many governments require utilities to tolerate nonpayment due to health concerns. For example, the NAACP cites stuff .... cite some more of Jack!! what mechanisms? savings constraints? intrahousehold bargaining; go look up her new paper!!!!

8. Appendix

8.1. Predicting Delinquency Visits

Table 8. Linear Probability of Receiving a Delinquency Visit

	(1)	(2)	(3)
Usage t-1	-0.0000150[a]	-0.0000186[a]	-0.0000225[a]
	(0.0000052)	(0.0000052)	(0.0000079)
Days Delinquent t-1	0.0000524[a]	0.0000581[a]	0.0000499[a]
	(0.0000016)	(0.0000016)	(0.0000020)
Unpaid Balance t-1	0.0000009[a]	0.0000009[a]	0.0000011[a]
	(0.0000001)	(0.0000001)	(0.0000001)
Single House	-0.0001480	-0.0001468	
	(0.0002032)	(0.0002050)	
Apartment	-0.0004173[b]	-0.0005555[a]	
	(0.0001861)	(0.0001869)	
Age of HoH	-0.0000398[a]	-0.0000373[a]	
	(0.0000040)	(0.0000040)	
HoH Low Skill Empl.	0.0005415[a]	0.0005333[a]	
	(0.0001827)	(0.0001830)	
HH Size	0.0003462[a]	0.0003482[a]	
	(0.0000363)	(0.0000364)	
Employed HH Members	-0.0002883[a]	-0.0002957[a]	
	(0.0000573)	(0.0000574)	
Location		✓	
Year $\times$ Month FE		✓	✓
Household FE			✓
N	1,951,543	1,948,783	1,951,543
Mean Visits Per Month	0.0072	0.0072	0.0072

Std. errors clustered at the HH-level. [c] $p<0.10$,[b] $p<0.05$,[a] $p<0.01$

8.2. Sample Construction

Merging the full sample from the connection survey to the billing data yields an initial population of 3,343,644 connection-months as described in Table 9. Non-residential accounts are first removed to ensure that results apply to household-level decisions. Due to some data inconsistencies, payment records are missing for some connections, which are excluded. Due to leaks, meter replacements, and meter reading errors, connections occasionally experience extremely high meter readings and bills. Consumption records above 200 m3 as well as bills and payments above 80,000 are censored to address these issues. Large negative payments and outstanding balances (due to reimbursements of billing errors) are also excluded due to likely measurement error. Households that connect during the sample or have large stretches of missing records are excluded by including only connections with over 30 months of data. Keeping only connections serving single households brings the final sample size to 2,123,335 household-months.

Table 9. Sample Construction

	Observations	Observations Removed
Initial sample	3,343,644	
Keep residential connections (excluding commercial)		414,615
Keep connections with payment records		68,509
Keep months with usage under 200 m3		8,669
Keep bills > -5,000 PhP and < 80,000 PhP		116
Keep unpaid bills > -5,000 PhP and < 80,000 PhP		5,893
Keep payments > -80,000 PhP and < 80,000 PhP		1
Keep connections with over 30 months of records		1,360
Keep connections serving a single household		721,146
Final sample	2,123,335	

8.3. Indirect Utility Function

$$v^{*}=\begin{cases}\alpha\ \ln(\frac{p_1-\sqrt{{p_1}^2-8\,L\,\alpha\,p_2+8\,Y\,\alpha\,p_2+4\,L\,\alpha^2\,p_2-4\,Y\,\alpha^2\,p_2}}{2\,p_2\,(\alpha-2)})- \\ \ln(\frac{(\alpha-1)\,(8\,L-8\,Y-4\,L\,\alpha+4\,Y\,\alpha)}{2\,(\alpha-2)^2}+ \\ \frac{(p_1\,\sqrt{{p_1}^2-8\,L\,\alpha\,p_2+8\,Y\,\alpha\,p_2+4\,L\,\alpha^2\,p_2-4\,Y\,\alpha^2\,p_2}-{p_1}^2)\,(\alpha-1)}{2\,p_2\,(\alpha-2)^2})\,(\alpha-1) & \text{if } L\geq\widehat{L} \\ \alpha\ \ln\left(-\frac{p_1-\sqrt{{p_1}^2-4\,L\,p_2}}{2\,p_2}\right)-\ln(Y)\ (\alpha-1) & \text{if } L<\widehat{L}\end{cases} \tag{11}$$

$$\widehat{L}=\frac{Y}{2\ (\alpha-1)}+\frac{\frac{Y\,p_2}{2}+\frac{{p_1}^2}{8}-\frac{p_1\,\sqrt{{p_1}^2-\alpha\,{p_1}^2+8\,Y\,\alpha\,p_2}}{8\,\sqrt{1-\alpha}}}{p_2}$$

8.4. Tariff Structure and Approximation

Table 10. Example Residential Tariff As Presented to Consumers

Usage (m3)	Price (PhP)
Under 10	104.12 /conn.
Over 10	180.79 /conn.
Next 10	19.26 /cu.m.
Next 20	25.50 /cu.m.
Next 20	33.56 /cu.m.
Next 20	40.16 /cu.m.
Next 20	45.23 /cu.m.
Next 50	50.21 /cu.m.
Next 50	56.37 /cu.m.
Over 200	58.74 /cu.m.

Mean tariff 2010-2015 with value added tax.
"conn." refers to connection.
"cu.m." refers to m3/month. 50 PhP~1 USD

Table 10 provides the monthly tariff structure as it is presented to consumers. Consumers face a fixed price as well as marginal prices for any usage above 10 m3. The government regulator gradually adjusts prices at roughly yearly intervals in order to ensure that the water company is able to exactly cover its costs. The marginal price is highly non-linear, accelerating quickly at low usage levels before slowly increasing at high usage levels. To achieve a tractable approximation of this price schedule, Table 11 fits a simple regression model predicting average price as a function of an intercept, p_1, and monthly usage levels, p_2. This model predicts that a increase in monthly usage of 10 m3 results in an increase in average price of 2.2 PhP/m3.

Table 11. Average Price and Monthly Usage

	Avg. Price: $\frac{\text{Bill (PhP)}}{\text{Usage (m3)}}$
Usage (m3)	0.22^{a}
	(0.01)
Intercept	20.23^{a}
	(0.17)
Household-Months	476,862

^{c} $p<0.10$, ^{b} $p<0.05$, ^{a} $p<0.01$

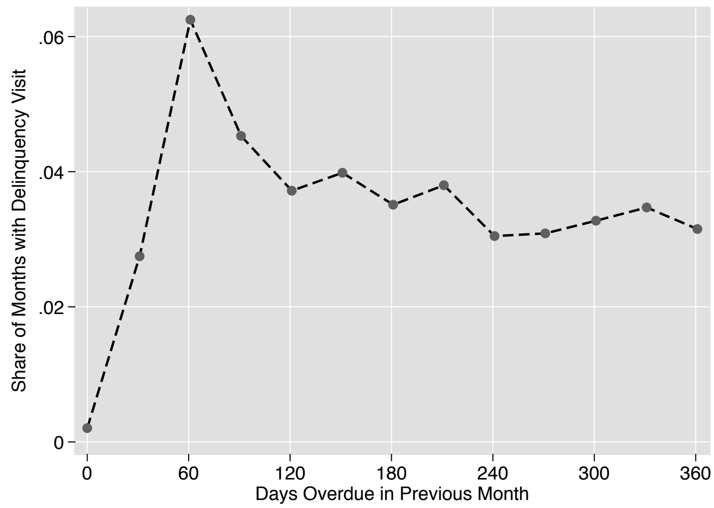
8.5. Stayer Descriptives

Table 12. Descriptives for Stayers

	Mean	SD	Min	25th	75th	Max
Usage (m3)	26.2	17.5	0.0	15.0	33.0	200.0
Bill	761	1,124	-4,640	287	920	78,409
Unpaid Balance	2,416	5,070	-4,995	261	2,346	79,904
Share of Months with Payment	0.60	0.49	0.00	0.00	1.00	1.00
Payment Size	1,214	1,498	0	426	1,482	61,298
Days Delinquent	84.9	155.4	0.0	0.0	91.0	720.0
Delinquency Visits per HH	1.32	0.61	1.00	1.00	2.00	6.00
Months Disconnected	0.03	0.17	0.00	0.00	0.00	1.00

Total Households: 8,260 Obs. per Household: 61.8 Total Obs.: 509,959

Figure 4. Stayers Share of Households that Receive a Delinquency Visit depending on Days Delinquent in the Previous Month



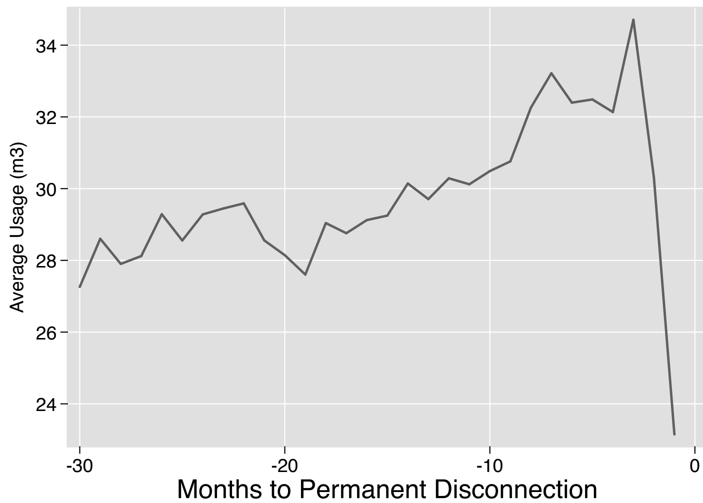
Only stayer households.

8.6. Usage Before Permanent Disconnection

don't like : Postpaid gives you more time to find the money. Water is a need, but money is not always available.

Figure 5 plots average usage across households according to the number of months before these households permanently disconnect. Average consumption increases in the months leading up to permanent disconnection. This increase is likely due to some households using water as if they faced a zero marginal price since they know that they will never pay their bills. With an average bill of 691.6 PhP/month, leaving an outstanding balance of 12,859 PhP at permanent disconnection is equal to enjoying an average of around 18 months of free water consumption.

Figure 5. Average Usage in Months Before Permanent Disconnection



Negative months indicate months before permanent disconnections.

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